RETrap - A Cryogenic Penning Ion Trap System - Status Report

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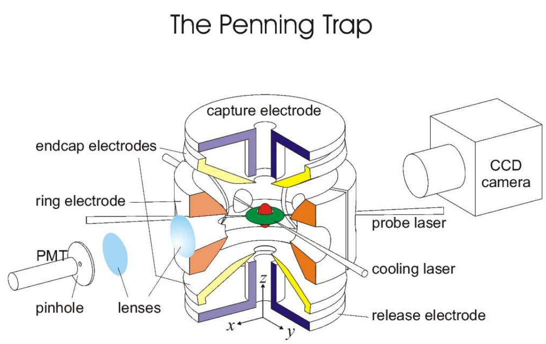

FIG. 1: Schematic of the Penning trap. It's a hyperbolic trap with six radial view ports to allow laser cooling, laser probing and fluorescence detection with high efficiency.

RETrap (Rare Element Trap) is a cryogenic Penning ion trap system which sits in a superconducting magnet that can produce magnetic fields up to 6 T. With this system, externally produced ions may be trapped and cooled to sub-Kelvin temperatures using both electronic and laser cooling. We intend to study precision atomic spectroscopy using lasers, the physics of cold, strongly-coupled plasmas (Coulomb crystals [1]) and aspects of nuclear physics related to weak interactions.

RETrap is located at the 88" cyclotron building above cave 3. It is operational and has presently two different MeVVA ion sources attached: beryllium and aluminium. RETrap is positioned such that it can also be coupled to the ECRs at the cyclotron which would open new possibilities. The schematic of the Penning trap is shown in Fig. 1. Ions entering the Penning trap from above are captured by lowering the voltage of the capture electrode for a short time (typical $\approx 10\mu$s) while the release electrode is kept at high potential. This confines the ions in the z-direction while the radial (x- and y-direction) confinement is accomplished by the magnetic field. We have trapped Be^+ and Be^{2+} ions. The trapped ions were detected by a tuned circuit attached to the endcap electrodes. While applying an rf field through the tuned circuit, the potential of the ring electrodes was lowered with respect to the endcap electrodes, forming an electrical harmonic potential in the z-direction. At a certain voltage difference, the axial oscillation frequency of the trapped ions (which depends on q/m) matches the frequency of the applied rf field and the ions absorb energy. This destructive detection method is shown in Fig. 2, where besides Be^+ and Be^{2+} ions, O^{2+} and N^{2+} ions were found to be trapped. The next step is to establish laser cooling of the Be^+ ions to cool Al^+ ions sympathetically. Since not every ion species has a suitable laser cooling scheme, we will always use laser-cooled Be^+ ions to sympathetically cool other ion species by Coulomb collisions [2]. With the Al^+ ions cooled, precise laser spectroscopy of the $3s^2\ {}^1S_0$ - $3s3p\ {}^3P_1$ transition will be performed. This interval has not been previously measured. Further proposed experiments are the measurement of the ground state fine structure splitting in Fe^{9+} (astrophysical red line of the solar corona) and Fe^{13+} (astrophysical green line) which would require a beamline to an existing ECR source at the cyclotron. The measurement of the anomalous magnetic moment of the radioactive isotope ${}^{24}_{11}Na^{5+}$ to test whether an EDM experiment is feasible, is also under consideration.

[1] L. Gruber et al., Phys. Rev. Lett. **86**, 636 (2001).
[2] D. Larson et al., Phys. Rev. Lett. **57**, 70 (1986).

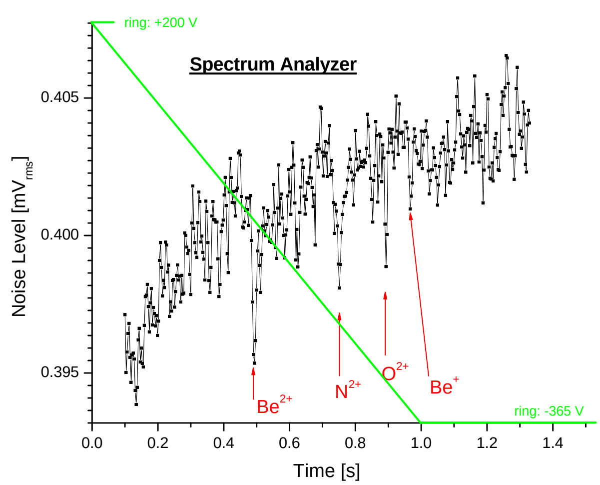

FIG. 2: Axial resonances of trapped ions.